1,225.5 for Site C, with a 95% confidence interval of 521.5 to 1929.5 (Scheaffer, et al., 1979). The coefficient of dispersion (variance to mean ratio) for the number of larvae per quadrat equals 0.987, which gives no evidence of non-random distribution (clumped or uniform) of larvae, at least at the scale of 1 m^2 quadrats.

The design of the larval study was such that all larval habitat was supposed to occur within the transect grid. During the latter part of the project several small outlying areas of larval habitat were found just east of the study area for site C. The collective size of these outlying communities was not deemed large enough to materially affect the study. Our best estimation is that the total square meter area of all of the other larval habitat at the Bruneau Dunes State Park including these outlying areas near site C does not exceed the total square meter area surveyed this year for site C. The total late-instar larval population for Cicindela arenicola at Bruneau Dunes State Park probably does not exceed 2,500 specimens, with a 95% confidence interval of 1,043 to 3,859.

Habitat Preference of Larvae

Larval burrows of all ages occurred in only 23 of the 825 quadrats surveyed. For these 23 quadrats there were only 12 burrows of the 4 mm diameter size. Larvae were most likely to occur in quadrats wherein the mix of surface materials was 30% sand, 40% gravel and 30% pebbles (Figures 2-4).

By using the frequency distributions of the quadrats without larvae as a measure of the available habitat, we can make several conclusions about the habitat preferences of larvae. First, larvae occur more than expected in areas of 30-40% sand, and substantially less than expected where coverage with sand was greater than 50% (Fig. 2). Larvae also were more common than expected in quadrats with gravel comprising 30-50% of the surface, and were less common than expected in areas where gravel was less than 10% of the surface (Fig. 3) . Larvae were

more common than expected in areas with a 20-40% pebble cover, and less common than expected where pebble cover was 10% or less (Fig. 4).

Larvae occurred more commonly than expected in areas with little vegetation cover. Over 90% of the burrows were in areas where the vegetation cover did not exceed 30% and nearly 50% of the larvae were found in areas with zero to 10% vegetation cover (Fig. 5).

Approximately 60% of the larval burrows occurred in areas categorized as uneven while 40% of the burrows occurred in the areas designated as even or level. However, since the uneven habitat is far more common (4.8 times as common), the larvae clearly prefer or survive better in areas that are even or level (Fig. 6).

Examination of how habitat affinities differ among age classes (Figures 7 and 8) should yield some insight into the mechanism that causes the preferences thus far discussed. If habitat preference is expressed by females laying eggs, then the three age classes should have similar frequency distributions. If females lay indiscriminately and habitat preference is caused by higher survival in some habitats than in others, then the age classes should have different frequency distributions, with 2 mm larvae distributed similar to plots with no larvae and 4 mm larvae showing a distinct preference. The actual result is closer to the latter, although low sample sizes make definitive determination impossible. Two mm and four mm larvae both appeared to have higher than expected occurrences at low percent of vegetation, indicating that a preference for non-vegetated areas is exhibited at the egg-laying stage.

Discussion

The density of burrows for the Dunes Tiger Beetle at Site C was quite low compared to that seen for several other species of tiger beetles in this part of Idaho. Larval densities for the populations of this beetle in eastern Idaho have not been reported. It is quite possible that they

are higher than those seen for western populations since the adults are reported to have much higher densities in the eastern populations as discussed previously.

The reliability of estimates made during a single year is questionable. First, the spring of 1992 was exceptionally wet and cold, and a phenological delay of two to three weeks was common for most events. The effect of this on adult beetle activity and density is difficult to estimate. Second, Cicindela arenicola requires two to four years to reach the adult stage (Bauer 1991). Accordingly, populations of adults may naturally have high and low years which are the result of good or bad habitat conditions over the one to three years preceding a count. The number of larval burrows could be affected in a similar fashion. To accurately or meaningfully inventory the population and assess population trends would require five or more years of annual monitoring for a species such as C. arenicola.

Late in the study (May 18 to June 4) after most of the survey work had been completed, high numbers of 2 mm diameter burrows appeared at many places within the area of Site C. The high number of these burrows (which are made by hatching larvae) indicated that a great amount of ovipositional activity had occurred even though the number of adults observed on any day was quite low. This would have occurred if peak adult activity occurred this year at times when no surveys were conducted. Another possible explanation is that multiple year diapause is known for certain stages of some insects so there is also the possibility that eggs of this species may lie inactive in the sand for more than one year before optimal conditions stimulate hatching. This would most logically occur in areas where the surface was stable from year to year such as the flat areas with gravel and pebbles. These areas would provide more protection for eggs than the open, changing dune habitat.

Anderson (1988) noted that the widespread occurrence of new larval burrows at the time of hatching reflected an apparent non-selective ovipositional behavior for females of the eastern

populations. By contrast, the new 2 mm diameter burrows at Bruneau Dunes State Park appeared almost exclusively within the flat areas, very few being found in the very sandy areas (see Plate 21). The analysis of the habitat data provides additional support for selectivity of habitat in choosing oviposition sites since 2 mm larvae tended to occur more than expected in areas with moderate sand and low vegetation cover.

Anderson (1989) indicated that this beetle did not occur on many of the dunes in Power Co. that were overgrown with vegetation. Such dunes were deemed by him to be "unsuitable for C. arenicola." The beetle apparently needs naked dunes in order to exist. We concur with him on this point and suggest that the low numbers of beetles at Bruneau Dunes State Park may primarily be due to vegetational encroachment upon the critical habitat for this species. Two exotic species of plants, Russian thistle and cheat grass, are quite common in much of the habitat where the larvae are found.

Overgrowth of these areas by weedy species could result in lower survival of larvae since they have evolved to live in open areas. The presence of vegetation would hinder burrow maintenance and could make the larvae more vulnerable to predators, parasites, and parasitoids. Vegetation could prevent the larvae from being able to throw out the sand balls, and vegetation situated directly above the burrow opening could complicate prey recognition by the tiger beetle larvae. This could interfer with effective capture of the prey. Shading could also adversely impact laraval success (see Plate 22).

Increased vegetation would also provide more cover and protection for lizards which can be a significant predator of adult tiger beetles (Pearson 1988 and Anderson 1990). It is quite possible that the beetles seek the open dune areas for foraging and mating so as to avoid predation by lizards. Leopard lizards were often spotted taking refuge in the vegetation of the sand hummocks. The female beetles are believed to enter the flats among the hummocks in order

to find ovipositional sites. It is of interest that this species was found most abundantly this year on these ovipositonal sites at the time of the first visitation. This was on April 20 with an air temperature of only 64 ° F. The lizards were not active under these conditions. We suggest that the early activity of this beetle may be an adaptation to avoid the increased risk of predation by lizards that comes with the warmer temperatures later in the spring.

It is the opinion of the writer that the most critical factor in the survival of C. arenicola at this time is the availability of adequate and undisturbed non-vegetated habitat that will support larval development for a two to four year period of time. This habitat needs to be in the close proximity of open dunes where the adults can forage and mate.

MANAGEMENT RECOMMENDATIONS

The several communities of the Dunes Tiger Beetle which occur in Owyhee Co. present a range of challenges if their continued viability is to be ensured. These populations and subpopulations can be formed into three groups for purposes of future monitoring and management.

Group one is a collection of smaller and rather scattered subpopulations within Bruneau Dunes State Park. These disjunct subpopulations occur in a general arc to the east, south and west of the main dunes complex within the park. Populations A and B in the reports written by Dr. Robert Anderson are included in this group.

Group two is the extensive subpopulation that is located along the east side of the low dunes complex located above the bluffs at a higher elevation in the southwest corner of Bruneau Dunes State Park. This area is also referred to as Site C or Population C in earlier reports.

Group three is the newly discovered Windmill Site. The beetles at the Windmill Site certainly qualify as a true biological population. The very isolated nature and very small size of this site

probably precludes regular genetic exchanges from occurring between this population and other populations.

Recommendations for Group One

It is recommended that present management practices continue for these scattered communities. It appears that the habitat available for successful larval reproduction is quite scattered and quite limited throughout the range of this group. It is very difficult to assess the impact of introduced species of plants on the vegetation pattern for these scattered areas; it is unknown if these species are increasing, decreasing, or stable. Such species as Russian olive trees and Russian thistle have certainly impacted the area and have produced changes in the landscape which may have caused the perceived decline in numbers of this species.

Vegetational overgrowth is probably deleterious to larval success. The dunes tiger beetle appears to need rather flat, open habitat for larval reproduction and is apparently adept at locating such areas as they form. This permits the species to colonize new areas to replace those that are no longer adequate due to changes in vegetation and dune topography. It is very probable that historically there have been short-term and long-term fluctuations in the population numbers of this species. Accordingly, it is virtually impossible to determine in one year whether or not current numbers of this species are really depressed due to man's impact or are at a low in a cycle that results from climatic fluctuations and natural biological factors.

It is unknown at this time if cattle or humans have adversely impacted the newly hatched larvae of this species during the hatching period when they are establishing their first larval burrow. This critical period occurred during late May and early June this year. It is generally quite hot by this time in the season and the elevated temperatures tend to reduce park visitations. The more isolated and less attractive areas which serve as breeding areas are rather infrequently used by visitors at this time. It is recommended that the use of these areas during this period,

especially by large groups, be discouraged. Should burrows be trampled by humans during other times of the year there is the possibility that at least the more mature larvae would be able to reopen the burrows. The impact of repeated trampling by humans, however, is unknown.

In the event that serious negative impacts brought about the demise of one or more of these scattered subpopulations there is a very high probability that recruitment from other nearby subpopulations would bring about recolonization. It is even possible that adults move about among several of these nearer areas. Should all of the subpopulations of this group gradually decline and fail, re-establishment would be possible from the larger subpopulation at Site C which is situated on higher ground southwest of the general park area.

It is recommended that the known larval habitat areas for group one be surveyed for the presence of mature larval burrows at least every two years so as to document the occupation of these sites by the dunes tiger beetle. The number of adult beetles seen on each of these surveys should also be recorded. Such survey work would complement that done this year and would provide data for monitoring the general trend in numbers for these scattered communities. These surveys should be conducted when weather conditions are proper for adult activity.

It is further recommended that the surveys be done when the sand lily (Leucocrinum montanum Nutt.) begins to flower (Plate 23). The initiation of activity by the dunes tiger beetle adults appears to coincide closely with the initiation of flowering by the sand lily. The monitoring of this plant would appear to provide a good guage for when the beetle commences surface activities. Calendar dates are less reliable since seasonal variation due to weather conditions can significantly advance or delay biological activity patterns. Adult beetles were seen on dunes at Site A on March 22 this year. No flowers were open on the sand lily although buds were evident.

Recommendations for Group Two

Group two is synonymous with population C of Anderson's report (1992). It is the largest subpopulation known for the Dunes Tiger Beetle in the western reach of its range. It was first discovered on April 28, 1992 at the time of the workshop by Anderson on this species. Plans call for the inclusion of this area within the boundary of the Bruneau Dunes State Park. The construction of a fence along the western and southern boundaries by the end of the 1993 calendar year will provide initial protection for this site. This subpopulation will then be included within the area protected by Bruneau Dunes State Park. The fence should efectively exclude cattle and off- road cyclists.

This dune system did not appear to be highly impacted by human activities during the spring months of this year. During the course of the survey work done from April to June of 1993 no humans were seen to visit this area. A few old wheel tracks from prior years were still visible. It is quite unlikely that hikers would utilize these more remote dunes. The low and rolling nature of these dunes offers little in the way of a recreational challenge for hikers. These dunes are not visible from the more highly developed recreational areas of Bruneau Dunes State Park situated at a lower elevation to the east.

Subpopulation C is well located for continued inventory and assessment studies since it is not generally impacted by human activity. Such studies would provide data so as to establish population trends and elucidate species' dynamics. This area already has an established, extensive transect system for the purpose of estimating the mature larval population. Annual counts of larval burrows should be done for at least the next five years so as to establish the population trend. Counts should also be done for adult beetles at the same time even though they are less reliable for reasons discussed above.

Subpopulation C may well represent a "source site" as discussed by Hubbell and Foster (1986). All other sites in the Bruneau Dunes complex may, at least in the short term, represent "sink sites". The larger, more successful subpopulation C is well-positioned to produce colonizers for the patchy larval habitat found downwind. Subpopulation C may be the stable reproductive base that persists while the other areas may come and go.

All the subpopulations within the Bruneau Dunes State Park should be considered as one biological population since they are probably close enough to permit regular genetic exchange, considering the known flight capabilities and habits of other species of tiger beetles. Adults of normally diurnal Cicindela marutha are known to oviposit at night on dunes up to 1 km away from their diurnal pond edge habitat, and specimens of Cicindela trifasciata have been collected at lights on offshore platforms 160 km from the nearest land (Pearson 1988).

Recommendations for Group Three

The Windmill Site should be carefully inventoried in 1994 in view of its small size and unprotected nature. The area needs to be carefully walked and mapped so as to delineate all the currently active larval habitat areas. Surveys for both adults and mature larvae should be conducted to establish a baseline for the numbers of both categories occurring in this population. At a minimum, three walk-through censuses for adults should be done during the flowering period of the sand lily (Leucocrinum montanum Nutt.). A transect study should be performed so as to estimate the number of mature larvae for this small population. A count of first instar burrows should be done at the time that the first instar larvae hatch and establish their first burrows. Such counts may prove to be valuable in determining the collective ovipositional activity in any year.

The density of the first instar larval burrows may be a very good indicator for the viability of populations of this beetle wherever it occurs. Observations at Site C this year indicated a great overproduction of first instar larvae relative to the number of later instar larvae that survive. There is the possibility, however, that eggs laid in one season may not hatch until the next year if hatching conditions are not proper for this species. Thus, there may be an accumulation of eggs for a few years with extensive hatchings in years of very heavy spring precipitation. Careful studies need be performed to resolve questions such as this.

If studies at the Windmill Site establish that these dunes are subject to human disturbance such as camping, offroad vehicles, or all terrain vehicles, then an exclosure fence should be established to protect the very limited area of habitat that supports larval development.

This population is of considerable biological interest in that it is so small and so isolated. Its small size allows for ready inventory of the total population at relatively little cost. It is not recommended, however, that more extensive ecological studies be done at this site, at least in the near future. Disruption associated with such studies could overtax this site. Any studies involving manipulation of plants, predators, or parasitoids would more appropriately be assigned to the larger Site C area of the Bruneau Dunes State Park.

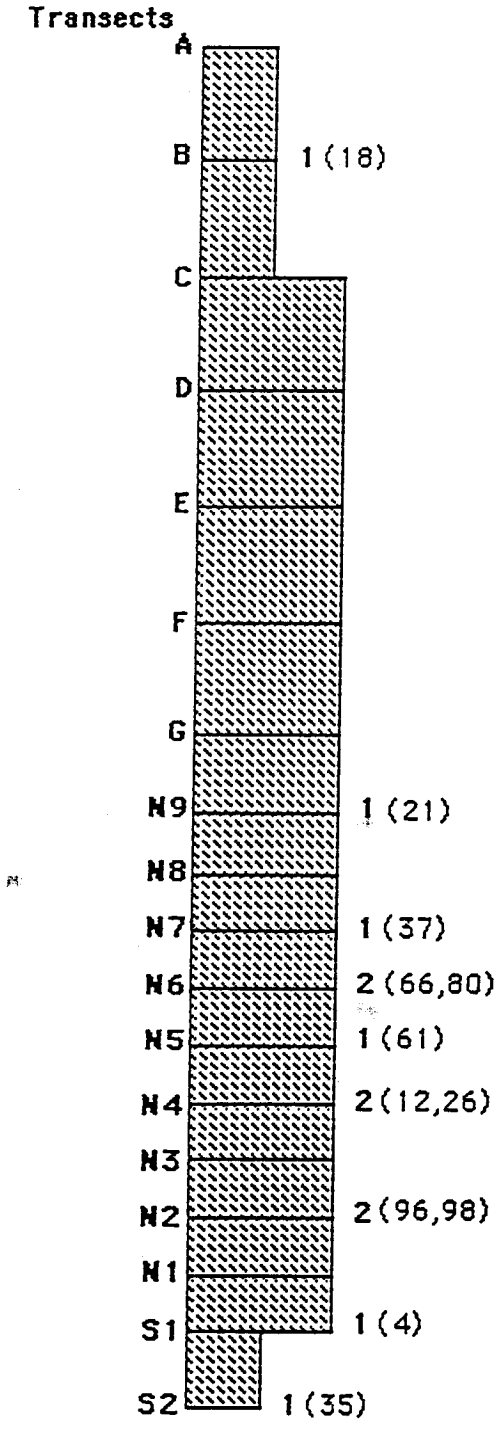


Figure 1
Schematic of area surveyed for larval burrows of Cicindela arenicola Rumpp at Site C. Transects A, B, and S2 are each 50 m long. All other transects are 100 m long. The distance between transects is to scale in this figure.

Bold numbers = number of 4 mm diameter burrows seen in that transect.

Number in parenthesis = number of the quadrat in that transect where the burrow was found.

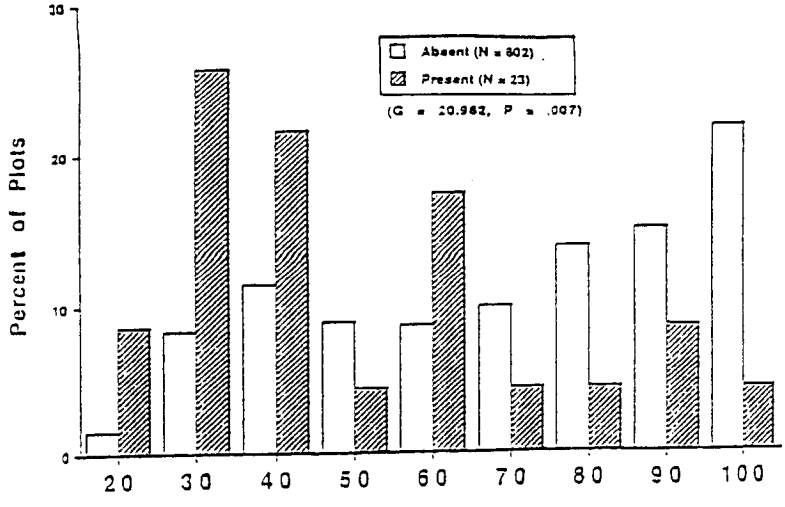
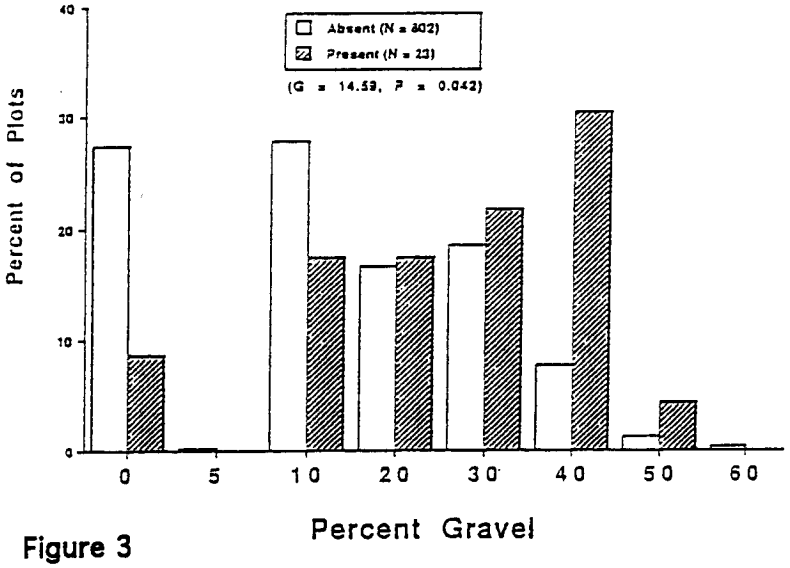


Figure 2



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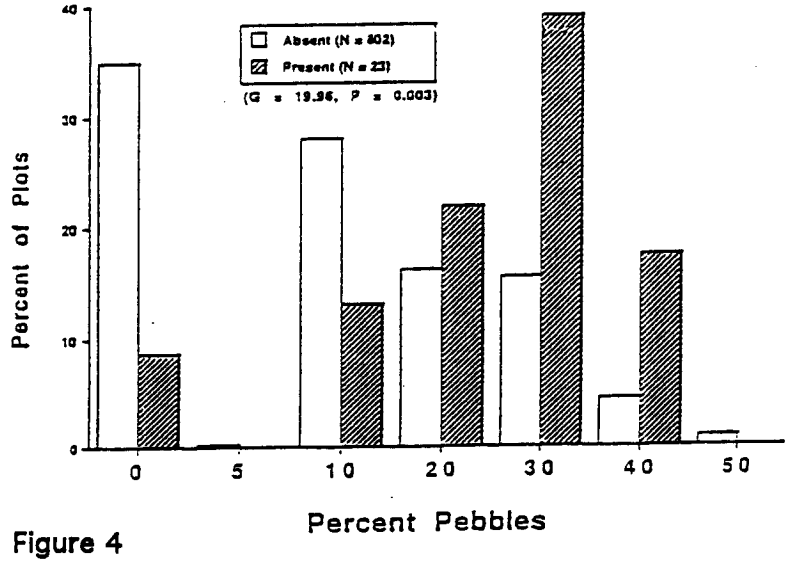

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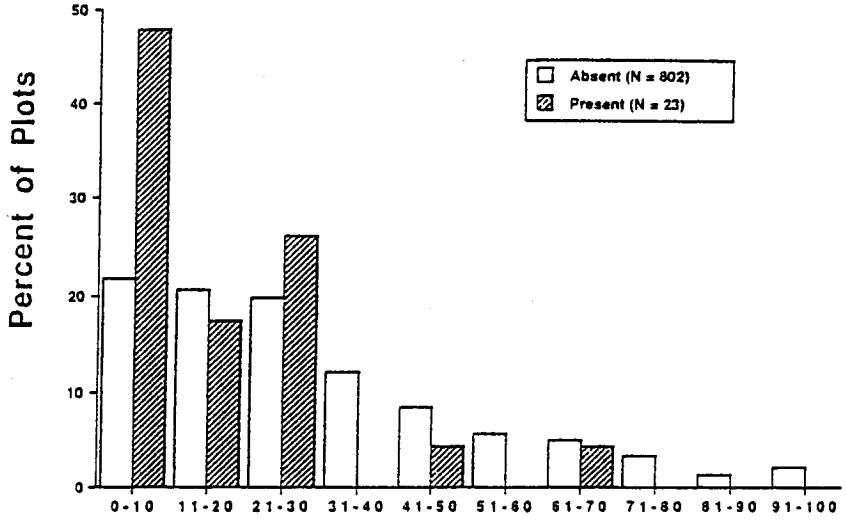

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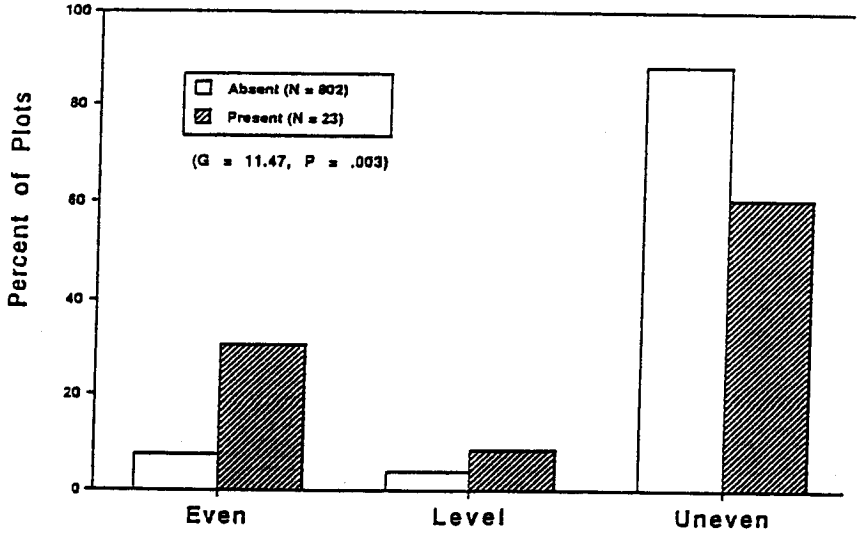

Figure 6